

Amendments to the Specification (other than claims):

Please replace the specification, apart from the claims, with the following substitute specification.

TITLE OF THE INVENTION

**TOOL PATH DATA GENERATION APPARATUS FOR NC MACHINE TOOL
AND NUMERICAL CONTROLLER PROVIDED WITH IT**

BACKGROUND OF THE INVENTION

~~Field of the invention~~

Technical Field

The present invention relates to ~~a tool-path data generation apparatus for~~
~~apparatuses that automatically generating~~generate tool-path data ~~in relation to~~
~~position data to~~, including transfer a tool pathway and cutting ~~conditions etc. of a~~
~~tool in an parameters, for cutting tools in numerical-control machining centers~~
("NC machine tools"), and also relates to ~~a numerical controller~~controllers
provided with such tool path data generation apparatus-es.

Description of the ~~Prior~~Related Art

As an apparatus for automatically generating tool path data ~~with~~by using
design data of an object to be cut (hereinafter referred to as a workpiece) being
created by CAD (Computer Aided Design), a tool path data generation apparatus
using a CAM (Computer Aided Manufacturing) method has been widely known.

Design data created by CAD (hereinafter referred to as CAD data)
comprises geometry data ~~indicating a final shape~~—for example, coordinate data,

formula data, and a dimension data on dimension lines—indicating final form and dimensions of the workpiece after being cut, for example, data in relation to coordinates and numerical formulas as well as dimension lines, etc. The tool path data generation apparatus extracts only workpiece geometry data of the workpiece from such CAD data, thereafter ~~receiving~~ timely receives data necessary to generate tool path data at any time through input by an operator operating the input unit, wherein such as data to be received includes data in relation to on features of the workpiece shape such as a form—as to whether the features will be circular shape, a rectangular shape, a conical shape, a round-columnar, square pillar, a convex curved surface-columnar, protruding contours, or a concave curved surface, recessed contours—and also data in relation to on cutting methods such as a kind type of tool and cutting conditions, through input by an operator operating an input unit, and finally generating generates tool path data on the basis of such input data and geometry data extracted from ~~above-mentioned~~ the CAD data.

However, in ~~the above-mentioned~~ described ordinary tool-path data generation apparatus, since data in relation to on the features of the workpiece shape as well as data in relation to on the cutting methods—both of which are necessary to generate tool path data—must be inputted by the operator, ~~it takes a long period to~~ the data input these data, whereby it also takes another long period to machine the workpiece process is time-consuming, such that machining of the workpiece is itself, time-consuming. In addition, it is very difficult to

completely prevent ~~artificial~~ human-caused input errors, ~~whereby such owing to~~
~~which problems that~~ such as the workpiece ~~is turning out~~ defective or the
~~workpiece jig and the cutting tool are being damaged might happen. These can~~
~~occur. Such~~ problems may cause ~~another other~~ critical problems in ~~such a~~
~~production to make one article off (custom) manufacture, for example a, the~~
~~production to make of~~ a mold.

If an expected result cannot be obtained because of ~~a tool chatter of tool~~
and ~~an overload in~~ caused by cutting when ~~creating~~ an NC cutting program is
created on the basis of tool path data generated by the tool path data generation
apparatus ~~and when, to carry out~~ machining by the NC machine tool ~~with using~~
the above-mentioned NC cutting program, it is necessary to correct the NC
cutting program after ~~a pursue of~~ investigating the causes ~~which may take a long~~
~~period, which can be time-consuming~~, further it is also necessary to trace back to
an initial cutting stage in the tool path data generation apparatus for executing
the above-mentioned correction. As a result it takes another long period to re-
output the NC cutting program, ~~whereby such that~~ the machine tool has to be
stopped during such period, consequently productivity is deteriorated.

In view of the foregoing, it is an object of the invention to provide a tool
path data generation apparatus which can speedily and securely generate and
correct tool path data on the basis of CAD data, and also to provide a numerical
controller provided with such a tool path data generation apparatus.

BRIEF SUMMARY OF THE INVENTION

In accordance with the invention for achieving the above object, ~~a tool path data generation apparatus automatically generates tool path data including data in relation to position data to transfer a tool and cutting (including grinding) conditions etc. of a tool in an NC machine tool, comprising~~ a tool path data generation apparatus for automatically generating tool path data including position data on where to transfer a tool and cutting (including grinding) conditions for the tool comprises: a feature data extractor for extracting ~~at least features in relation to a three-dimensional shape of a workpiece, on the basis of CAD-device-created geometry data of the~~ on a workpiece created with using CAD, to be machined by the machine tool, at least feature data relating to the three-dimensional final form of the workpiece; a tool/cutting data storage for storing data ~~such as a~~ including cutting-mode and tool information ~~in accordance with a feature shape, a cutting determined by the extracted feature data, and cutting-speed and a depth-of-the-cut in accordance with workpiece information determined by the material, etc., of which the workpiece consists;~~ a cutting method ~~setting~~ determining unit for ~~setting~~ determining an optimal cutting method for each ~~feature shape of the final-form features of a workpiece, on the basis of~~ the extracted feature data extracted by the feature and on the basis of the data extractor besides on the basis of information stored in the tool/cutting data storage, and; a tool path data generator for generating tool path data on the basis of the ~~set~~ cutting method determined by the cutting method determining

unit; and a machining information generator for generating, on the basis of the cutting method determined by the cutting method determining unit and on information stored in the tool/cutting data storage, machining information including tool consumption to machine to final form, estimated time to tool wear-out, and estimated time to machine to final form.

According to the tool path data generation apparatus in relation to the present invention, firstly ~~data such as data in relation to, for example, on dimension lines etc.,~~ which is thought to be unnecessary in generating tool path data, is removed from workpiece design data ~~of the workpiece created with by using CAD;~~ next, only geometry data necessary to generate tool path data is extracted; finally, at least features ~~in relation~~ relating to the three-dimensional geometry of the workpiece are extracted from the above-mentioned geometry data by the feature data extractor. Here, ~~the~~ features of the workpiece's three-dimensional ~~shape~~ final form mean such geometric features of the workpiece ~~such as a circular shape, a, rectangular shape, a conical shape, a, round-columnar, and square pillar, a convex curved surface, or a concave curved surface etc.~~ columnar forms, as well as protruding and recessed contours.

Next, ~~the optimal cutting method is set for each feature shape by the cutting method setting unit~~ on the basis of the extracted feature data ~~extracted by the feature data extractor~~ as well as information stored in the tool/cutting data storage, the cutting method determining unit determines an optimal cutting method for the final-form features. Here, the cutting method includes several

cutting modes such as ~~a~~ contour line cutting, ~~a~~ scanning line cutting, ~~a~~ circular interpolation, ~~a~~ ~~straight line~~ linear interpolation, and ~~a~~ cutting direction ~~etc.~~, and also includes ~~a~~ kind type of tool, cutting conditions, feed pitch in a repetitive cutting of a specific cut cycle, and ~~a~~ cutting order in each machining area ~~etc.~~. Thus, tool path data is automatically and sequentially generated by the tool path data generator on the basis of the ~~set~~ determined cutting method.

As ~~above mentioned~~ described above, in this invention, because an operator neither has to input ~~neither data in relation to~~ on the ~~feature shape~~ final-form features of the workpiece, nor data ~~in relation to~~ on the cutting method, such as the kind type of tool and the cutting conditions, ~~therefore a period taken~~ the time required for ~~a~~ data input can be completely eliminated, whereby there is such an advantage that tool path data can be speedily generated, ~~which may lead another advantage such that the workpiece can be speedily cut.~~ leading to other advantages such as enabling rapid machining of a workpiece. Further, since any artificial error in an ~~no~~ no input-operation never happens, ~~the workpiece is occasioned human errors can occur, workpieces will be not defective and,~~ now will the jig and ~~the~~ cutting tool ~~are not be~~ be damaged. ~~These~~ These advantages of the present invention ~~may~~ can become even more conspicuous in such a ~~production to make one article for example a production to make~~ pronounced in custom manufacture, such as the production of a mold.

Here, tool path data in this invention includes all information in the NC machine tool necessary to operate it, such as data in relation to position data to

transfer a tool, spindle speed, and feed rate ~~in the NC machine tool necessary to operate it~~, meaning a basic data to generate an NC cutting program, and motion data for the purpose of ~~direct~~ directly driving a servo mechanism ~~finally afterward~~.

In ~~addition~~, a ~~setting~~ the further aspect of the invention, determining a cutting method in the cutting method ~~setting~~ determining unit can be smoothly executed when on the machining area is divided for each basis of feature shape of data extracted by the feature data extractor a workpiece is divided into machining areas corresponding to the final-form features so as to effectively ~~set~~ determine for each machining area division the optimal cutting method. Therein, the tool path data generator generates tool path data for each divided machining area on the basis of feature data extracted by the feature data extractor. At this period, the tool path data generator generates tool path data for each divided machining area division on the basis of the cutting method set methods determined by the cutting method ~~setting~~ determining unit.

~~The tool path data generation apparatus in relation to the present invention further comprises an information generator. According to this aspect of the invention, cutting-related to cutting for generating information related to cutting such as a consumption amount of a tool, an estimated period taken for a wear of the tool, and an estimated period taken necessary for a preparatory work on cutting on the basis of the cutting method set by the cutting method setting unit and also on the basis of information stored in the tool/cutting data storage. According to the present invention, information related to cutting necessary to~~

~~set up~~ can be obtained, whereby it is possible to easily and speedily execute the ~~setup of preparatory work on~~ cutting by the NC machine tool. An optimal cutting ~~hours (a time (during daytime or a during nighttime))~~ can be appropriately selected through an estimation of the cutting period. When it is judged that the cutting will be finished ~~for in~~ a short period, the cutting operation is done during ~~a the~~ daytime when people ~~is are~~ in, thereafter it is possible to cut or set up ~~a~~ next workpiece, which can improve productivity. On the other hand, when it is judged that it should take a long period for the cutting, it is possible to select a unmanned ~~time during the night time.~~ Since ~~a~~ cost needed to complete a completion of the workpiece can be ~~preparatively~~preparatorily computed before ~~an actual cutting thereof~~the workpiece is actually machined, because the necessary number of ~~the cutting~~ tools and ~~a period taken~~the amount of time for the ~~cutting machining operation~~ can be previously ~~decided, therefore a~~ ~~speedy~~determined, rapid estimation of the cost is enabled.

~~It is better to output the~~ The cutting methods set determined by the above-~~mentioned described~~ cutting method ~~setting determined~~ unit and also by information related to cutting -generated by the information generator related to cutting are preferably output as cutting scenarios ~~owing to a~~ by means of a further provided cutting scenario output unit. Thus, even when the expected result cannot be obtained because ~~of the tool~~ chatter ~~of tool~~ and ~~the~~ overload ~~etc. occur~~ in the actual cutting, causes relating to those problems can be ~~speedily pursued~~rapidly investigated by making reference to the output cutting scenarios.

The cutting scenarios herein mentioned mean the cutting method and information related to cutting as ~~above mentioned~~described above.

Further, there are other preferable embodiments ~~in relation to the~~involving a tool path data generation apparatus according to the present invention. In one such ~~that~~embodiment, the tool path data generated by the tool path data generator ~~can be output with being~~is converted to theinto an NC cutting program ~~owing to~~by means of a further provided NC cutting program generator, and ~~an~~the thus-generated NC cutting program is output externally by means of a further provided NC cutting program outputting unit, in addition. In another such ~~that~~above mentionedembodiment, the tool path data ~~can be output with being~~is converted into motion data ~~owing to~~by means of a further provided motion data generator, and ~~an~~the thus-generated motion data is output externally by means of a further provided motion data output unit. Thus, the obtained cutting program and motion data can be directly inputted into a numerical controller of the NC machine tool ~~through an on-line cutting~~online, or can be inputted into the numerical controller through a recording ~~media~~medium such as a floppy disc ~~etc.~~. Thus, according to these preferable embodiments of the present invention, ~~an~~ operability of the NC machine tool can be improved because tool path data can be generated without ~~being interlocked~~interfacing with the NC machine tool ~~or through an~~, that is, tool path data can be generated off-line cutting. Motion data herein mentioned means data to directly drive the servo mechanism etc. of the NC machine tool.

On the other hand, according to the numerical controller ~~in of~~ the present invention, ~~the a~~ workpiece can be ~~cut~~machined by executing generated tool path data at ~~any an arbitrary~~ time, or executing it ~~at the data in~~ real time. Here, the present invention relates to ~~the a~~ numerical controller ~~which controls an for~~ controlling operation of ~~the an~~ NC machine tool on the basis of tool path data including ~~the~~ position data on where to transfer a tool and ~~the~~ cutting conditions ~~of for~~ the tool, comprising either ~~of~~ the tool path data generation apparatus provided with the NC cutting program generator and the NC cutting program outputting unit, or ~~that the~~ tool path data generation apparatus provided with the motion data generator and the motion data output unit, and further comprising an executing unit ~~to for~~ sequentially ~~execute~~ executing processes on the basis of tool path data generated by the tool path data generator ~~and, so as~~ to control the operation of ~~above mentioned the~~ NC machine tool.

~~The A~~ numerical controller ~~in relation to~~ involving the present invention in yet a further aspect controls the operation of ~~the an~~ NC machine tool on the basis of tool path data including ~~the~~ position data on where to transfer a tool and the cutting conditions for the tool, ~~and the cutting conditions of the tool, comprising the comprises:~~ a tool path data generation apparatus, as described in the foregoing; a cutting scenario storage ~~which stores for storing~~ the cutting ~~method set~~ methods determined by the cutting method ~~setting~~ determining unit, ~~and and~~ machining information ~~related to cutting~~ generated by ~~the the~~ machining information generator ~~related to cutting, the executing unit which;~~ an executing

unit for controlling operation of the NC machine tool by sequentially ~~executes the~~
executing processes on the basis of tool path data generated by the tool path
data generator, ~~and receives interruption signals for~~ by temporarily stopping the
~~processes while receives resuming signals for resuming~~ on receiving interrupt
signals, and restarting the processes ~~so as to control the operation of the NC~~
~~machine tool, on receiving resume signals;~~ and a cutting scenario rewriting unit
for rewriting the cutting ~~method~~ methods stored in the cutting scenario storage.

According to the present invention, when the expected result cannot be
obtained, the cutting machining is temporarily stopped by inputting the
interruption signals into the executing unit. And after the cutting method stored in
the cutting scenario storage and/or information related to cutting have been
appropriately changed through the cutting scenario rewriting unit, tool path data
is regenerated; thereafter the cutting can be re-started according to the
regenerated tool path data. As mentioned above, according to the present
invention, for changing generated tool path data, the corresponding cutting
method etc. can be speedily corrected; therefore ~~a~~ the series of operations from
~~a~~ the generation of tool path data to ~~a~~ the final cutting of the workpiece can be
executed ~~for in~~ a short period. ~~Especially in the production to make one article~~ In
particular, in an operation for producing a single article—for example ~~the~~
~~production to make one~~ an operation to produce a single mold, an advantage of
the present invention ~~has an advantage such is~~ that generated tool path data can
be promptly corrected to re-start the cutting machining.

~~Further, in the numerical controller in relation to~~ In a still further aspect of
the present invention, the foregoing numerical controller is further provided with a
tool/cutting data updating unit, ~~knowledge obtained through above-mentioned~~
~~cutting can be reflected on a continuing cutting~~ for updating data stored in the
tool/cutting data storage by referring to data₁ stored in the cutting scenario
storage₁ that has been rewritten as ~~mentioned above and by updating data~~
~~stored in the tool/cutting data storage described earlier, to reflect in a continuous~~
machining operation knowledge obtained as described above from machining
operations.

In addition, ~~in~~ according to the present invention a numerical controller
embodied as just described may be further provided with a data base output unit,
~~data stored in the tool/cutting data storage which has been~~ for outputting
~~updated is preferably output through the data base output unit.~~ data stored in the
tool/cutting data storage. Thus, above-mentioned output data is inputted into the
tool path data generation apparatus provided apart from the numerical controller
for updating the data-base thereof, consequently the above-mentioned
knowledge can be effectively reflected ~~on~~ in the generation and processing of tool
path data in the tool path data generator.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a block diagram showing main components of a numerical
controller in accordance with first embodiment of the invention.

Fig. 2 is a perspective view showing one example of ~~a~~the geometry of a workpiece obtained from geometry data in accordance with the first embodiment.

Fig. 3 is an explanation drawing explaining process contents in a feature data extractor in accordance with the first embodiment.

Fig. 4 is an explanation drawing explaining process contents in a feature data extractor in accordance with a second embodiment.

Fig. 5 is another explanation drawing explaining process contents in the feature data extractor in accordance with the second embodiment.

Fig. 6 is the other explanation drawing explaining process contents in the feature data extractor in accordance with the second embodiment.

Fig. 7 is an explanation drawing showing one example of data stored in a tool/cutting data storage in accordance with the first embodiment.

Fig. 8 is a block diagram showing main components of a tool path data generation apparatus in accordance with the second embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Now, specific embodiments of the invention will herein~~below~~ be described below with reference to the accompanying drawing-s.

Firstly, a first embodiment of the invention will be described with reference to Fig. 1. Fig. 1 is a block diagram showing main components of a numerical controller in accordance with this embodiment.

As shown in Fig. 1, a numerical controller 1 of this embodiment comprises a geometry data generator 4, a feature data extractor 6, a cutting scenario generator 9,

a tool/cutting data updating unit 10, a cutting scenario rewriting unit 12, a tool path data generator 13, a data generation monitor 15, ~~each generation unit of processing sections, which are~~ a motion data generator 17 and an NC cutting program generator 19, a CAD data storage 3, a geometry data storage 5, a feature data storage 7, a tool/cutting data storage 8, a cutting scenario storage 11, a tool path data storage 14, an evasion data storage 16, ~~each storing unit of storage sections, which are~~ a motion data storage 18 and an NC cutting program storage 20, an input/output interface 21, and an input unit 22 and an output unit 23 connected to the input/output interface 21, all of which are mutually connected to each other through a bus line 2. In addition, ~~each operation unit~~ units of an NC machine tool as an external apparatus ~~is~~ are connected to the input/output interface 21.

The CAD data storage 3 is a functioning unit to store CAD data in relation to the workpiece, wherein such CAD data is inputted through an on-line ~~processing process~~ or through a recording ~~media~~ medium such as a floppy disc from the input unit 22. Above-mentioned CAD data is usually created ~~with~~ by using an apparatus provided apart from the numerical controller 1 of this embodiment, ~~including and includes~~ design data indicating a final shape and a dimension of the workpiece, ~~—~~ for example coordinates data and numerical formula data in relation to the workpiece shape as well as data of a finished surface precision, workpiece material and workpiece shape. Here, such CAD data usually includes data unnecessary to generate tool path data, for example data ~~in relation to on~~ dimension lines etc.

The geometry data generator 4 is a process unit which removes from CAD data stored in the CAD data storage 3 the above-mentioned data in relation to the described data on dimension lines etc. unnecessary to generate tool path data ~~from CAD data stored in the CAD data storage 3~~, extracting only data necessary to generate tool path data. Geometry data extracted by the geometry data generator 4 is stored in the geometry data storage 5. One example of the geometry of the workpiece ~~will be~~ is shown in Fig. 2 ~~in a visual manner on the basis of geometry data stored in the geometry data storage 5. As shown in Fig. 2, a workpiece 30 has a wavy curved area 31 (a free curved surface), and a convex area (a quadrangular pyramid body) 32 and a concave area 33 both of which are formed on the wavy curved area 31.~~

The feature data extractor 6 is another process unit which recognizes ~~a specific machining area in an area decided,~~ on the basis of geometry data stored in the geometry data storage 5, a specific machining area (in which a workpiece is machined) in a site determined according to the geometry data, then ~~extracting~~ extracts features in relation to ~~a the~~ three-dimensional geometry of the workpiece within above-mentioned recognized machining area. An extraction and processing of the features comprises two processes, ~~one is being~~ a simple geometry extraction that is a comparatively simple process so as to extract comparatively simple geometric elements, ~~for example a conical shape round- or a square pillar shape etc. of columnar on~~ the workpiece, which can be directly extracted from geometry data within above-mentioned the recognized machining

area; the other is ~~an~~ being a free-form surface extraction of a feature shape of a free curved surface that, which is a little bit somewhat complicated process ~~so as to extract the~~ in which, for a free-curved-form surface etc. which that cannot be directly extracted from the geometry data within same, the feature shape in the machining area, is extracted.

The extraction of the feature ~~shape geometry~~ of the free curved surface will be herein ~~below~~ described below in detail. In this embodiment, such extraction is executed ~~with~~ by using a pattern projection method. ~~The~~ In the extraction which uses ~~above-mentioned the~~ pattern projection method ~~is to project,~~ a virtual image formed of small triangles is projected on the surface of the workpiece obtained from ~~above-mentioned the~~ geometry data, as shown in Fig. 3, thereafter ~~deciding a normal on~~ normals are determined to each small triangle which has been imaged on the surface of the workpiece, and analyzing the direction of each normal so as to extract the geometric feature of the workpiece as a result. Fig. 3 indicates a condition when the virtual image is projected on the workpiece 30 as shown in Fig. 2.

For example, as shown in Fig. 4, ~~in an area 34 of a circular truncated cone shape, each normal 35 of same area is spread in a radial manner without crossing with each other.~~ 4, in a frustum-shaped geometric feature 34, the normals 35 to the geometric feature 34 spread radially without intersecting. As shown in Fig. 5, ~~in an area a geometric feature 36 having a vertical plane, each normal face, the normals 37 of same area is provided in a~~ the geometric area 36

parallel ~~manner each other~~. As shown in Fig. 6, in ~~an a geometric~~ area 38 having a slant, ~~each normal~~ed face, the normals 39 of same area has a specific ~~in the~~ geometric feature 38 have a given angle. ~~When an area has a concave shape (not shown), each normal of same area crosses with each other. In instances of a recessed/hollowed geometry (not shown), the normals intersect.~~ Thus, the feature ~~shape~~geometry of the workpiece can be decided by analyzing the direction of the normal-s. ~~In the extraction of extracting the feature shape of the geometry of a free curved surface, the feature shape geometry is extracted through above-mentioned described method. Thereafter, feature data (area data and data in relation to the feature shape geometry) which has been extracted through above-mentioned described method is stored in the feature data storage~~ 7.

The tool/cutting data storage 8 is a section functioning ~~unit~~ to store tool information and cutting information, ~~concretely to say, storing a cutting~~ specifically, to store, according to each feature geometry, machining mode according to each feature shape (for example a (such categories as contour line cutting, a scanning line cutting, a straight line linear interpolation, a circular interpolation, and a kind of evasion course of "air cut etc." (empty-travel) evading process), a kind type of tool (types model, material etc.), tool information such as a diameter of tool etc., a cutting speed set determined for each kind of tool in accordance with the type of tool, depending on the material of the workpiece, and data in relation to a cutting amount and an on depth-of-cut and a cutting

~~allowance for cutting etc.~~ Here, one example of data stored in the tool/cutting data storage 8 is shown in Fig. 7.

The cutting scenario generator 9 executes two processes; ~~one is being to~~ decide an optimal cutting method on the basis of data stored in the tool/cutting data storage 8, and also on the basis of feature data stored in the feature data storage 7; ~~the other is being to~~ generate information related to cutting on the basis of the decided cutting method. ~~A setting and processing of the~~ The cutting method ~~is to search~~ determining process is for searching the tool/cutting data storage 8 on the basis of feature data ~~for setting an~~ to determine the optimal cutting mode, ~~an optimal kind~~ type of tool to ~~be used~~ use, and ~~an optimal cutting condition etc.~~ conditions for each machining area, for each machining area, ~~setting a~~ determining the feed pitch based upon ~~finished~~ final surface roughness of ~~a the finished surface etc.~~ surfaces of the workpiece when ~~a repetitive cutting is requested in~~ cutting is carried out by repeating a specified processing cycle, ~~on the other hand, continuously cutting machining area as many as possible and,~~ when a common tool ~~should be~~ is used in ~~many machining area,~~ thus ~~deciding a cutting order for each~~ plurality of machining area ~~with considering a~~ areas, for allowing the plurality of machining areas to be machined as continuously as possible, thus for deciding order of cutting for machining areas in consideration of cutting efficiency. Here, the setting and processing of the cutting method can be much more easily and speedily executed when the machining area is further

divided into a plurality of small ~~area~~areas in accordance with the feature shape, then above-mentioned cutting method is ~~set~~determined for each small area.

A-~~The~~ generation and processing of information related to cutting is ~~to~~ generate-for generating information in relation to the cutting (operation (machining information related to cutting) ~~such as a)~~ including tool consumption amount of a to machine to final form, estimated time to ~~tool, a period taken for the tool to reach a wear limit thereof (estimation),~~ out, tool set-up data of the tool, a period taken for preparing for the cutting (estimation), a period taken, estimated time to prepare for the cutting ~~(estimation), and a cutting operation,~~ estimated time the cutting operation will take, and estimated machining cost (estimation) etc. Thus, ~~decided~~determined cutting method and information related to the cutting operation are both stored in the cutting scenario storage 11 as cutting scenarios.

In the numerical controller 1 in accordance with this embodiment, a process in the tool path data generator 13 is executed after each process ~~has been sequentially executed~~ in the feature data extractor 6 as well as in the cutting scenario generator 9- has been sequentially executed.

The tool path data generator 13 is a process unit ~~to-for~~ sequentially ~~generate~~generating tool path data including position data on where to transfer a tool, spindle speed, and the tool feed rates ~~of the tool for each~~ machining ~~area~~areas according to the ~~set~~determined cutting order on the basis of the cutting scenario ~~especially, in particular,~~ the cutting method stored in the cutting

scenario storage 11. Here, generated tool path data is transmitted to the tool path data storage 14 and the data generation monitor 15 in ~~order~~sequence. The tool path data storage 14 is a section functioning unit to store received tool path data in ~~order~~sequence, storing all tool path data generated by the tool path data generator 13. The data generation monitor 15 is a process unit ~~to for~~ temporarily ~~keep~~holding received tool path data, then ~~transmit~~transmitting it to the motion data generator 17 in accordance with a transmission request therefrom.

The motion data generator 17 is a process unit ~~to generate~~for generating motion data for directly driving a servo mechanism provided in the NC machine tool, generating motion data on the basis of received tool path data, outputting generated motion data to ~~an operation unit~~units 24 of the NC machine tool through the input/output interface 21, and transmitting such motion data to the motion data storage 18. The motion data storage 18 stores all motion data generated by the motion data generator 17, while each operation unit 24 of the NC machine tool is driven on the basis of received motion data, whereby the workpiece is ~~cut~~machined. Here, the motion data generator 17 plays ~~a the~~ role ~~as of~~ an executing unit as set forth in claim 7.

As ~~above mentioned~~set forth above, in the numerical controller 1 in accordance with this embodiment, ~~a generation of tool path data and a cutting of the machining of a workpiece~~ can be executed and processed ~~at in~~ real time.

The data generation monitor 15 monitors ~~an the~~ amount of ~~data being kept,~~ ~~concretely to say, transmitting data~~ being held, and in particular, transmits data

in accordance with ~~the a~~ request from the motion data generator 17 as described above when the amount of data being ~~kept held~~ surpasses a specified value; on the other hand, ~~transmitting~~ the data generation monitor 15 transmits a process ~~stopping order-halting command~~ to the motion data generator 17 when the amount of data being ~~kept held~~ becomes less than ~~above-mentioned the~~ specified value, then ~~obtaining~~ obtains information in relation to an evading operation from the evasion data storage 16, ~~thereafter generating~~. The data generation monitor 15 then generates tool path data to make the tool evaded from a cutting position, and ~~transmitting~~ transmits such data to the motion data generator 17, while ~~obtaining~~ and meanwhile obtains information in relation to a comeback operation from the evasion data storage 16 when the amount of data being kept again rises above the specified value, and thereafter ~~generating~~ generates tool path data to make the tool ~~come come~~ back to the original cutting position ~~and transmitting~~, and transmits such data to the motion data generator 17. In the motion data generator 17, motion data in accordance with tool path data is generated, while the NC machine tool executes ~~the above-mentioned described~~ evading operation.

Since it takes ~~a period time~~ to generate tool path data for a ~~little~~ bit somewhat complicated geometry such as a free ~~curved form~~ surface ~~etc.~~, it might happen during a real-time ~~processing process~~ that tool path data for the next operation has not been generated ~~even though a~~, despite completion of a ~~present current~~ operation. In this case, trouble ~~such an inconvenience might happen that a as~~ cutter mark ~~could be marked on the marks marring a~~ workpiece

because the tool ~~substantially contacts with the workpiece for a long period, is in~~
prolonged contact with the workpiece could occur; however, such
~~problem~~problems can be effectively evaded through ~~above-mentioned evading~~
~~operation. Here, the above-described evading operation. Here, the evading~~
operation data (~~an the~~ evading operation pattern) in accordance with the cutting
mode has been previously stored in the evasion data storage 16 through the
input unit 22.

The data generation monitor 15 transmits ~~a process stopping orders,~~
halting command to the tool path data generator 13 and the motion data
generator 17 for halting their processes when an interruption signal is inputted
from the input unit 22 ~~for stopping the processes, on the other hand, transmitting;~~
meanwhile, the data generation monitor 15 transmits process re-starting orders
to the tool path data generator 13 and the motion data generator 17 when a re-
start signal is inputted for re-starting the processes.

An operator might judge through ~~a~~ monitoring that it is possible to machine
the workpiece at higher cutting speed than that ~~being previously set in the~~ having
been determined in advance by the cutting scenario generator 9 and also that it
is possible to make ~~a~~ the feed rate faster, or the operator might judge oppositely
based upon his experience. Further, he might judge that depth of cut in the
direction of ~~a~~ the tool axis as well as in the direction of ~~a~~ the tool diameter of ~~tool~~
should be changed. ~~At this time~~ In such instances, the operator inputs ~~the~~
~~interruption~~ an interrupt signal ~~from~~ through the input unit 22, ~~whereby~~ which

enables a process in the data generation monitor 15 to change the cutting speed, the feed rate, and the depth of cut ~~can be changed by the data generation monitor 15.~~

As ~~above mentioned~~ explained above, the data generation monitor 15 stops the processes in the tool path data generator 13 and the motion data generator 17 when the interruption signal is inputted, making possible ~~a rewrite~~ rewriting of the cutting scenario stored in the cutting scenario storage 11, ~~while transmitting and meanwhile transmits~~ the re-starting ~~orders~~ command to the tool path data generator 13 and the motion data generator 17 when the re-start signal is inputted after data has been rewritten, thereafter re-starting the processes. Thus, following ~~cuttings~~ cutting operations are all executed under ~~a the~~ the rewritten cutting condition-s. The foregoing description ~~hereinbefore mentioned~~ is to ~~change for changing~~ the cutting condition during the execution of ~~the a~~ cutting process. ~~At this time, the cutting operation.~~ Therein, the cutting operation can be returned to its initial stage then re-started under the ~~changed condition~~ altered conditions.

The correction of the cutting scenario as above mentioned is executed by the cutting scenario rewriting unit 12, wherein the cutting scenario rewriting unit 12 receives the input data from the input unit 22 ~~then, and then rewrites~~ data stored in the cutting scenario storage 11 ~~is rewritten~~. The output unit 23 is composed of a display apparatus, a printing apparatus, and an apparatus to store data in a recording ~~media~~ medium such as a floppy disc ~~etc., indicating~~

~~each, for whereby the output unit 23 display apparatus displays~~ data stored in the CAD data storage 3, ~~in~~ the geometry data storage 5, ~~in~~ the feature data storage 7, ~~in~~ the tool/cutting data storage 8, ~~in~~ the cutting scenario storage 11, ~~in~~ the tool path data storage 14, ~~in~~ the evasion data storage 16, and ~~in~~ the motion data storage 18 ~~by the display apparatus, while printing such data by the printing apparatus, storing it in, the output unit 23 printing apparatus prints the data, and the output unit 23 store the data onto the recording media such as the floppy disc etc. Therefore, the medium. Thus, an operator can indicate on the display apparatus a cutting scenario stored in the cutting scenario storage 11 on the display apparatus, or can actually perform the above-mentioned described correction of the cutting scenario after the analysis of same the scenario through a print-out. Here, the output unit 23 plays a role as the roles of a cutting scenario output unit as set forth in claim 4, a motion data output unit as set forth in claim 6, and a database output unit as set forth in claim 10.~~

When data stored in the cutting scenario storage 11 is rewritten, data stored in the tool/cutting data storage 8 is updated by the tool/cutting data updating unit 10. That is to say, the tool/cutting data updating unit 10 refers to data stored in the cutting scenario storage 11 which has been rewritten, thereafter updating corresponding data stored in the tool/cutting data storage 8. Knowledge obtained through ~~an actual cutting~~ machining operations can be reflected ~~on a following cutting owing to above-mentioned in subsequent machining operations by means of the~~ data updating function, ~~which means that~~

explained above, enabling a NC machining center embodying a tool path data generation apparatus according to the present invention to acquire a learning function can be acquired through the actual cutting through the machining operations the center actually carries out.

In this embodiment, the NC cutting program generator 19 is provided to generate an NC cutting program from tool path data which has been generated as mentioned above. The NC cutting program generator 19 is a process unit ~~to generate a~~ for generating generally used NC cutting ~~program~~ programs (for example, ISO formats) on the basis of tool path data stored in the tool path data storage 14, wherein the generated NC cutting program is stored in the NC cutting program storage 20. ~~The output unit 23 also indicates~~ displays In turn, data stored in the NC cutting program storage 20 is displayed by the output unit 23 on ~~the~~ its display apparatus, ~~printing~~ printed out such data by ~~the~~ its printing apparatus, ~~storing such data~~ and stored in ~~the~~ a suitable recording media ~~such as the floppy disc etc. Therefore, the~~ medium. The generated NC cutting program is thus stored in ~~the~~ a recording media ~~through which~~ medium, whereby the NC cutting program will be able to be executed in another NC machine tool. Here, the output unit 23 also ~~plays a role as~~ functions in the capacity of a program output unit as set forth in claim 5.

As described above, according to the numerical controller 1 in accordance with this embodiment, the operator has to input neither data in relation to the feature shape of the workpiece nor data in relation to the cutting method such as

the kind of tool and the cutting conditions thereof, therefore ~~a period taken for~~
~~at the time required for~~ data input can be completely eliminated, ~~whereby there is~~
~~such an yielding the~~ advantage that tool path data can be speedily generated,
~~which may lead another in turn leading to the~~ advantage ~~such that~~ the workpiece
can be speedily cut. Further, since ~~any artificial error in an~~ no human-caused,
~~input-operation never happens~~ errors can ever occur, the ~~workpiece is machined~~
workpieces are free of defects and the ~~tool is not cutting tools are kept from~~
being damaged. ~~These~~ These advantages of the present invention ~~may can~~
become even more conspicuous in such a pronounced in custom manufacture,
for example, the production to make one article for example of a production to
make one mold.

There is further advantage that a corresponding correction can be speedily
and appropriately applied to generated tool path data which has some points to
be improved or defects, because such generated tool path data is executed ~~at in~~
real-time and ~~at its~~ cutting ~~condition thereof~~ conditions can be changed during a
~~cutting process the machining operation~~. As a result, ~~a the~~ series of operations
from ~~a the~~ generation of tool path data to ~~a the~~ final cutting of the workpiece can
be completed ~~for in~~ a short period. ~~In above mentioned production to make one~~
~~article for example the production to make one~~ An advantage with mold, there
fabrication or other custom manufacturing is such an advantage that the
cutting machining can be ~~spontaneously~~ immediately re-started through a
correction of the generated tool path data.

Next, a second embodiment of the invention will be described with reference to Fig. 8. Fig. 8 is a block diagram showing main components of the tool path data generation apparatus in accordance with the second embodiment.

As shown in Fig. 8, a tool path data generation apparatus 41 is provided ~~apart~~separate from the NC machine tool, having a different construction from that of the numerical controller 1 ~~in relation to~~ involving the first embodiment ~~in such a point that it doesn't~~, in that the tool path data generation apparatus 41 does not comprise the numerical controller 1, the tool/cutting data updating unit 10, the cutting scenario rewriting unit 12, the data generation monitor 15, and the evasion data storage 16 ~~as well as in such a point that it isn't~~, and in that the tool path data generation apparatus 41 is not connected to ~~each~~the operation ~~unit~~units 24 of the NC machine tool. Hence, since components of the tool path data generation apparatus 41 in accordance with this embodiment are all included in the components of the numerical controller 1, the same ~~codes~~reference marks are given to the same components in the tool path data generation apparatus 41 as those in the ~~tool path data generation apparatus~~ numerical controller 1 ~~with omitting~~, and a detailed explanation thereof ~~explanation of those like components are herein omitted~~.

According to the tool path data generation apparatus 41 in accordance with this embodiment, a generated NC cutting program is directly transmitted to the externally provided numerical controller of the NC machine tool or is inputted into the numerical controller of the NC machine tool ~~after above-mentioned NC cutting program has been~~ once the above-described NC cutting program has been stored in

a suitable recording media such as a floppy disc etc. medium. Thereafter, the cutting program is executed in the NC machine tool to cut the workpiece.

As ~~mentioned~~described above, the tool path data generation apparatus 41 in accordance with this embodiment is provided ~~apart~~separate from the NC machine tool, and is thus provided such that it operates without ~~interlocking~~interfacing with the NC machine tool, whereby tool path data can be generated irrespective of ~~any the~~ operating condition of the NC machine tool. Therefore, ~~an~~ operability of the NC machine tool can be improved.

Here, if the numerical controller comprises at least the cutting scenario storage 11, the tool path data generator 13, the motion data generator 17, the input/output interface 21, and the input unit 22, the cutting scenario generated by the tool path data generator 41 in accordance with second embodiment is directly transmitted to the numerical controller through an on-line processing or is inputted into the numerical controller ~~after the cutting scenario has been once~~ the cutting scenario has been stored in the recording ~~media such as the floppy disc etc., medium, and~~ thereafter tool path data and motion data are generated in ~~order~~sequence by the numerical controller ~~so as to be processed. Here, the cutting scenario doesn't have a large capacity not like the NC cutting program but more~~ It will be appreciated that the cutting scenario, unlike immense-volume NC machining programs, is of compact volume, therefore the cutting scenario can be transmitted from the tool path data generator 41 to the numerical controller ~~through an on-line processing and processed at~~ online to enable real-time machining at any time.

On the other hand, in the numerical controller 1 in accordance with first embodiment, the cutting scenario is outputted from the numerical controller 1 and then is inputted into the tool path data generator 41, whereby tool path data can be generated by the tool path data generator 41 ~~with~~by using the inputted cutting scenario. Further, if the tool path data generator 41 is provided with the cutting scenario rewriting unit 12 just like in the numerical controller 1, the cutting scenario of the second embodiment can be appropriately corrected by the tool path data generator 41 at any time. ~~On the other hand,~~ Meanwhile, if the tool path data generator 41 is provided with the tool/cutting data rewriting unit 10, data stored in the tool/cutting data storage 8 can be automatically updated. Thus, the operability of the NC machine tool can be effectively improved through an off-line processing owing to ~~such~~which an advantage is that tool path data can be generated by both ~~of~~ the numerical controller and the tool path data generator ~~with~~ using the cutting scenario. In addition, ~~it is also possible to generate the cutting scenario~~ can be generated by tracing back through ~~a trace back of the NC cutting program so as to generate geometry data~~. This process should be executed when CAD data itself must be corrected to ~~cut~~machine the workpiece ~~to an expected~~according to a desired geometry.

While certain present preferred embodiments of the invention have been described, and it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied within the scope of the following claims.